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[54] **SATELLITE DIRECT RADIO BROADCAST SYSTEM**

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[52] **U.S. Cl.** **370/316**; 370/319; 370/320; 370/330; 455/12.1; 455/13.1; 455/3.2

[58] **Field of Search** 370/49.5, 97, 50, 370/104.1, 307, 316, 319, 320, 330; 455/4.1, 4.2, 5.1, 6.1, 6.2, 6.3, 13.3, 3.2, 12.1; 348/10, 11, 12, 13, 7, 6

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,789,142	1/1974	Shimaski et al.	179/15
4,425,639	1/1984	Acampora et al.	370/97
4,480,328	10/1984	Alaria et al. .	
4,931,802	6/1990	Assal et al.	370/97
5,473,601	12/1995	Rosen et al.	370/319
5,485,464	1/1996	Strodtbeck et al.	370/319
5,625,624	4/1997	Rosen et al.	370/319

OTHER PUBLICATIONS

S. Joseph Campanella, *Communications Satellites: Oribiting Into The 90's*, IEEE Spectrum, pp. 49–52, Aug. 1990.

G. Losquadro, *Digital Audio Broadcasting: High–Grade Service Quality Through On–Board Processing Techniques*, Centre for Satellite Engineering Research, Jul. 31, 1995.

Maral, Gerard, *VSAT Networks*, pp. 52–53 (John Wiley & Sons, Ltd., 1995).

Chitre, D.M., "The Role of Satellite Communications in the ISDN Era", International Journal of Satellite Communications, vol. 10, No. 5, Sep.–Oct. 1992, pp. 210–215.

Chitre, D.M. et al, "*Architectures for the Intelsat NISDN–Compatible Satellite* Communications Network", International Journal of Satellite Communications, vol. 10, pp. 217–225 (1992).

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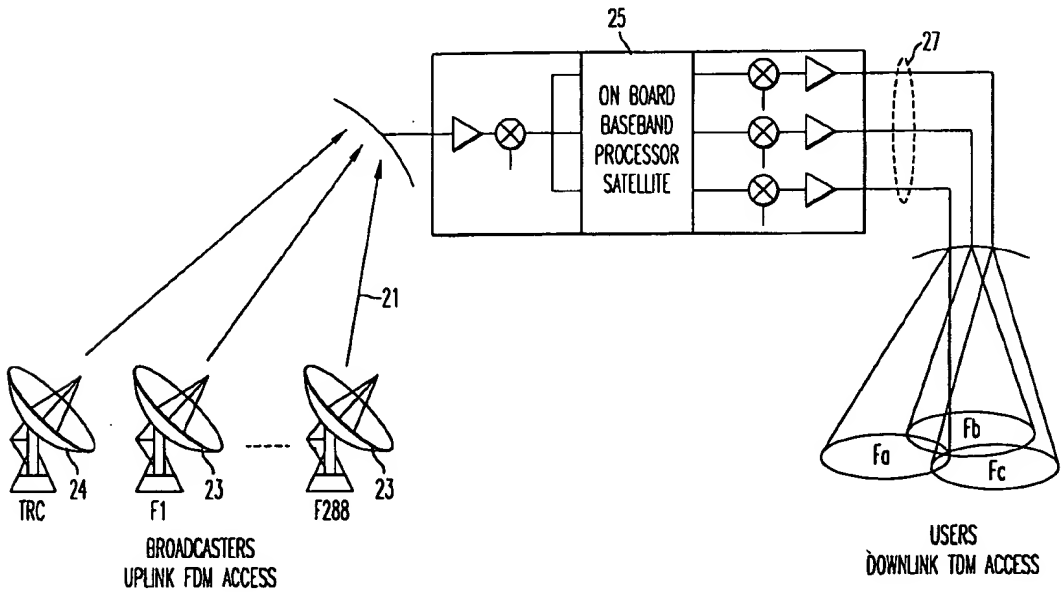
[57] **ABSTRACT**

A satellite direct audio broadcast system includes a plurality of fixed-rate, uniform, frequency division multiple access ("FDMA") uplinks and a time division multiplexed ("TDM") downlink. Source audio channels may be divided among and transmitted through a selectable number of fixed-rate uplinks so as to have selectable audio quality at the receiver. Fixed-rate FDMA uplinks include information designating related channels as containing related source information. On-board the satellite baseband processing selects uplink information channels for inclusion into none, one or multiple TDM downlinks. Transmitted audio information may be scrambled, and authorization downloaded to receivers to permit descrambling for paid subscription service.

16 Claims, 7 Drawing Sheets



operating with solar power or batteries. The radio will receive the L band signal, demodulate and extract from the TDM stream the useful audio signal, and expand the sound into its original form.

FIG. **7** illustrates program signal processing in a portable radio receiver in a satellite communication system of the present invention. Such a low cost radio receiver, equipped with a small compact patch antenna **131** having about 4 to 6 dBi gain, will require virtually no pointing and will tune automatically to selected channels. An alternative higher end radio will be equipped with an antenna that achieves 10 to 12 dBi of gain. Since such an antenna would be quite directional, it is pointed to achieve best reception. One version of this antenna may be an array of patches. The array may be embedded conformally into the surface of the radio case, attached as a lid or be completely detachable and connected to the radio by a thin coax cable a few meters long. Another version of the antenna could be a helix operating in either a broadside or end-fire mode. Pointing is done by rotating the antenna in elevation and azimuth. A detachable antenna might be mounted on a small tripod on the ground or mounted to a window frame and pointed to achieve best reception. A 10 dBi antenna has a beam width of approximately 65° and consequently will be easy to point at the satellite for achieving optimum reception. The directivity of this antenna will further enhance reception in locations where reflections might otherwise cause interference. A phased array, rod shaped antenna with wide beamwidth in one dimension but narrow in the other (i.e. a fan beam) is another alternative. Yet an alternate antenna could be a spiral antenna for outdoor reception and most indoor reception. In certain environments (mask, concrete or metal buildings), indoor reception may require connection to an external antenna. For reception by mobiles, antennas with as little as 4 dBi of gain may be mounted on the vehicle. A single antenna of this type would operate very well in an open location at high elevation angles, devoid of severe multipath reflectors. However in an area having multipath reflections, such as downtown cities, where elevations are less than 60°, measures may occasionally have to be taken to mitigate the multipath interference. One such measure is to use two or three of the 4 dBi gain antennas in a spatial diversity array mounted at various locations on the vehicle. These would be dynamically added to achieve directivity or combined so as to pick the maximum signal arrival at a given instant. Another alternative is to install a steerable fan beam directional antenna with 10 dBi of gain and make it track the satellite. This latter idea is expensive but people of means may well prefer its use to maximally benefit from the high performance quality offered by the system. As satellite mobile systems come into worldwide use in the next decade, electronically steerable array antennas are expected to drop in price and become generally affordable.

A time division multiplexing, multiple channel per carrier technique is used for downlink transmission to the radios. Each of the prime rate (16.056 kilobits per second) channels occupies its own time slot in the time division stream. These prime rate channels are combined to carry program channels ranging from 16 to 128 kilobits per second. Use of digital techniques allows for ancillary services to the radio including slow motion image, paging, mailing, fax, use of flat screens or serial interface. This data and information may be multiplexed within the audio digital signal channels.

Each radio receiver can tune to one of the 1.767688 million symbol per second TDM carriers transmitted in one of the beam coverages. As shown in FIG. **7**, a low noise amplifier **133** boosts the satellite signal, and the boosted signal is received in a chip set **135**. The chip set **135** includes a receiver **137**, demodulator **139**, time division demultiplexer **141** (which recovers the prime rate channels) and forward error correction ("FEC") decoder **143**. The output of the chip set **135** is a baseband digital signal.

The instructions needed for the receiver to control recombination of the coded prime channels into the coded program channels are contained in the control word imbedded in each coded prime rate channel. The recombined coded program channels thus recovered are decoded and deinterleaved to recover the original baseband prime rate bit stream that entered the system at the broadcaster's earth terminal. The recovered bit streams are next converted back to the analog audio signal by a source decoder **145**. The system can reproduce various audio qualities ranging from AM monaural to CD stereo depending on the program channel bit rate.

The user will control the whole functionality with five knobs. All information will appear on an LCD with 80 characters. For all system control functions an 8 bit micro controller with integrated LCD driver will be used. The integrated LCD driver allows the use of cheap LCD without any additional logic and reduces the number of parts needed. The microcontroller should provide 16 kByte ROM, 512 kbyte RAM.

Subscription Service

The system may incorporate subscription service under which certain program channels may be received only after a subscriber (radio receiver owner/user) has paid for service. The broadcaster of the subscription channel scrambles the broadcast. Unpaid receivers would receive a noise-like signal. A paid subscriber would then have his/her radio authorized to descrambler the subscription channel. Such descrambling can be accomplished by a decryption key.

Authorization can be accomplished in one of several ways. In a first method, the paid subscriber inserts a smartcard or memory card containing authorization to descramble the selected channel. The smartcard could also be equipped with a digital payment program that accounts for time and usage, or a debit card that is initialized with a payment amount and decrements as the receiver is used. (When the payment decrements to zero, the subscriber must pay for additional authorization.) In a second method, the paid subscriber could deliver his/her receiver to an authorized agent who downloads the required authorization through a digital data port on the receiver. In a third method, each radio receiver would have a unique, embedded identification number, and the broadcaster could include a one-bit-per-frame control channel within the broadcast preamble. When a subscriber pays for the service, the broadcast channel addresses the radio and provides an authorization signal. By whatever method, a specially designed microchip would be preferred to control authorization, either in the smart card or in the receiver itself.

After learning of the embodiments described above, people practicing in this art will be able to make variations that fall within the spirit and scope of the invention. The embodiments described above are exemplary but not intended to limit unduly the scope of the invention as defined by the following claims.

What is claimed is:

1. A receiver for receiving a time domain multiplex downlink signal comprising a plurality of time division multiplex channels, the time division multiplex downlink signal having been generated from selected ones of a plu-

rality of prime rate channels which are combined and multiplexed by a space segment, the space segment obtaining the prime rate channels from at least one uplink used to transmit information comprising prime rate channels from a number of broadcast stations, the receiver comprising:

an antenna for receiving said downlink signal;

a demodulator for demodulating said downlink signal to recover a time division multiplex bit stream; and

a demultiplexer for demultiplexing said prime rate channels from said time division multiplex bit stream, said prime rate channels each comprising a control word indicating to which of a plurality of broadcast programs each said prime rate channel belongs, and for recombining said prime rate channels corresponding to a selected broadcast program using said control word in each of said prime rate channels corresponding to said broadcast program.

2. The receiver of claim 1 wherein each of said prime rate channels is a uniform rate channel.

3. The receiver of claim 2 wherein different numbers of said uniform rate channels are combined to create respective ones of said plurality of broadcast programs having different bit rates, said receiver being operable to recover said uniform rate channels corresponding to said selected broadcast program using said control word in each of said uniform rate channels.

4. The receiver of claim 3 wherein said plurality of broadcast programs are characterized by different qualities of service corresponding to said different bit rates.

5. The receiver of claim 4 wherein said selected broadcast program is characterized by a quality of service selected from a group of qualities of service consisting of amplitude modulated monaural signal quality, frequency modulated monaural signal quality, frequency modulated stereo signal quality, and optical disc stereo signal quality.

6. The receiver of claim 1 wherein said selected broadcast program comprises a first group of prime rate channels in said plurality of prime rate channels 3 corresponding to an audio program and a second group of prime rate channels in said plurality of prime rate channels corresponding to an ancillary program, said control word in each of said prime rate channels of said first group and said second group comprising data relating said first group and said second group to said selected broadcast program and said prime rate channel corresponding to said control word to one of said first group and said second group.

7. The receiver of claim 6 wherein said ancillary program comprises at least one type of data selected from the group consisting of video, text, graphics, paging signals, database data, and file transfer data.

8. A receiver for receiving an encrypted, time domain multiplex downlink signal comprising a plurality of time division multiplex channels, the time division multiplex downlink signal having been generated from selected ones of a plurality of prime rate channels which are combined and multiplexed by a space segment, the space segment obtaining the prime rate channels from at least one uplink used to transmit information comprising prime rate channels from a number of broadcast stations, the receiver comprising:

an antenna for receiving said downlink signal;

a demodulator for demodulating said downlink signal to recover a time division multiplex bit stream;

a demultiplexer for demultiplexing a plurality of prime rate channels from said time division multiplex bit stream, said prime rate channels each comprising a control word indicating to which of a plurality of broadcast programs each said prime rate channel belongs, and for recombining said prime rate channels corresponding to a selected broadcast program using said control word in each of said prime rate channels corresponding to said broadcast program; and

a subscription service device operable to disable said receiver from descrambling said downlink signal until an authorization signal is provided to said receiver, and to enable said receiver to decrypt said downlink signal after said authorization signal is provided thereto.

9. The receiver of claim 8 wherein said subscription service device comprises an input device for a card provided by a user, said card bearing data representing a decryption key for at least one of said time division multiplex channels, and said input device being configured to detect said data on said card and to decrypt said at least one of said time division multiplex channels.

10. The receiver of claim 9 wherein said card provides said user with a digital payment method selected from the group consisting of providing a credit account to bill said user for the duration said card is used to decrypt one of said time division multiplex channels, and providing a debit account and decrementing said debit account an amount corresponding to use of said card, said subscription service device being operable to disable said receiver when said debit account has a zero balance.

11. The receiver of claim 8 wherein said subscription service device comprises a memory device for storing a decryption key, said decryption key being provided to said memory device only after said user is authorized to use said receiver.

12. The receiver of claim 8 wherein said subscription service device comprises an input device for allowing a user to enter a unique identification code, said selected broadcast program comprises an authorization code, and said subscription service device is operable to compare said authorization code and said unique identification code and to disable said receiver if said authorization code and said unique identification code are different and to enable said receiver if said authorization code and said unique identification code match.

13. A method of receiving a broadcast program at a receiver via a space segment, broadcast programs being transmitted as uniform rate channels in at least one uplink to the space segment, the space segment combining and multiplexing selected ones of the uniform rate channels into a time division multiplex downlink signal, the method comprising the steps of:

receiving the time division multiplex downlink signal from the space segment, the time division multiplex downlink signal comprising a plurality of the uniform rate channels corresponding to the broadcast program, each of the uniform rate channels having a control word indicating that the uniform rate channel is related to another uniform rate channel;

demultiplexing the time division multiplex downlink signal to recover the uniform rate channels transmitted therein; and

recombining the uniform rate channels corresponding to the broadcast program using the control word in each of said uniform rate channels corresponding to the broadcast program.

14. A communication system for the broadcast and reception of programs comprising:

a plurality of frequency division multiplex uplinks, each uplink including at least one information channel, the

programs consisting of a variable number of uniform rate channels that are each characterized by a minimum signal rate, the information channel in each uplink comprising at least one uniform rate channel corresponding to a respective one of the programs, each uniform rate channel having a corresponding control word, the system being programmable to combine uniform rate channels corresponding to at least one program and located in different information channels into a digital signal group having a higher signal rate than the minimum signal rate and to provide the control word in each uniform rate channel in the digital signal group with at least one bit to indicate that the uniform rate channel belongs to the digital signal group;

a space segment for receiving the uplinks, restoring data from the information channels to baseband data, and combining the baseband data from selected information channels into at least one time division multiplexed signal; and

at least one time division multiplex downlink including the time division multiplexed signal;

wherein each control word comprises data selected from the group consisting of data representing a number of related digital signal groups, data uniquely identifying the digital signal group to which a uniform rate channel associated with the control word belongs, data representing the number of the uniform rate channels in the corresponding digital signal group, data uniquely identifying the uniform rate channel corresponding to the control word, data representing a number of sub-ensembles constituting at least one digital signal group, data representing the number of uniform rate channels in a sub-ensemble, and data uniquely identifying a sub-ensemble.

15. A communication system for the broadcast and reception of programs comprising:

a plurality of frequency division multiplex uplinks, each uplink including at least one information channel, the programs consisting of a variable number of uniform rate channels that are each characterized by a minimum signal rate, the information channel in each uplink comprising at least one uniform rate channel corresponding to a respective one of the programs, each uniform rate channel having a corresponding control word, the system being programmable to combine uniform rate channels corresponding to at least one program and located in different information channels into a digital signal group having a higher signal rate than the minimum signal rate and to provide the control word in each uniform rate channel in the digital signal group with at least one bit to indicate that the uniform rate channel belongs to the digital signal group;

a space segment for receiving the uplinks, restoring data from the information channels to baseband data, and combining the baseband data from selected information channels into at least one time division multiplexed signal;

at least one time division multiplex downlink including the time division multiplexed signal; and

a receiver configured to receive the time division multiplex downlink, to demultiplex the uniform rate channels transmitted in the time division multiplex downlink, and to recombine the selected information signals corresponding to the program using the control words.

16. A method of broadcasting a program to at least one receiver via a space segment comprising the steps of:

formatting a program into a plurality of uniform rate channels, each uniform rate channel having a corresponding control word indicating that the uniform rate channel is related to another uniform rate channel;

modulating the uniform rate channels onto different ones of a plurality of frequency division uplinks;

processing the uplinks via the space segment to recover the uniform rate channels as baseband data;

routing the baseband data into selected time slots in at least one time division multiplex downlink signal;

receiving the time division multiplex downlink signal from the space segment;

demultiplexing the time division multiplex downlink signal to recover the uniform rate channels transmitted therein; and

recombining the uniform rate channels corresponding to the program using the control word in each of the uniform rate channels corresponding to the program.

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